Mechanical Force Considerations in the Use of EMI-Envioronmental Gaskets

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ABSTRACT

There are many types of EMI-Environmental gaskets on the market, where the cost and maintainability considerations associated with their use are just as important as the EMI and environmental sealing quality. Two critical factors associated with the cost and maintainability are the type of fastener to be employed in holding a cover or door tight against the gasket seal and the spacing of the fasteners. This paper illustrates four (4) equations that can be employed to answer these questions, where the equations yield the fastener spacing and force based upon variables associated with the gasket to be used, and the cover and shielded enclosure material and construction constraints. The paper describes the equations, lists the important gasket variables associated with the Spira EMI-Environmental gasket line and illustrates examples of the use of the equations.

INTRODUCTION

EMI-Environmental gaskets are used extensively in the electronic and aerospace industry to assist in obtaining shielding from electromagnetic fields. EMI gaskets perform their sealing function by providing a low impedance path from the cover to the shielded enclosure around the entire periphery of the hole or apperature being sealed. This low impedance path is obtained by exerting a force on the gasket by the lid or cover. Figure 1 and associated views illustrates a typical gasketed joint. As is illustrated in View C-C of the figure, the gasket will force the cover to bow. The objective in the mechanical design is to maintain sufficient force at the mid-point between the screws (see view B-B of figure 1) to obtain a minimum required impedance. If an environmental seal is required, then the objective of the design is to provide sufficient force mid-way

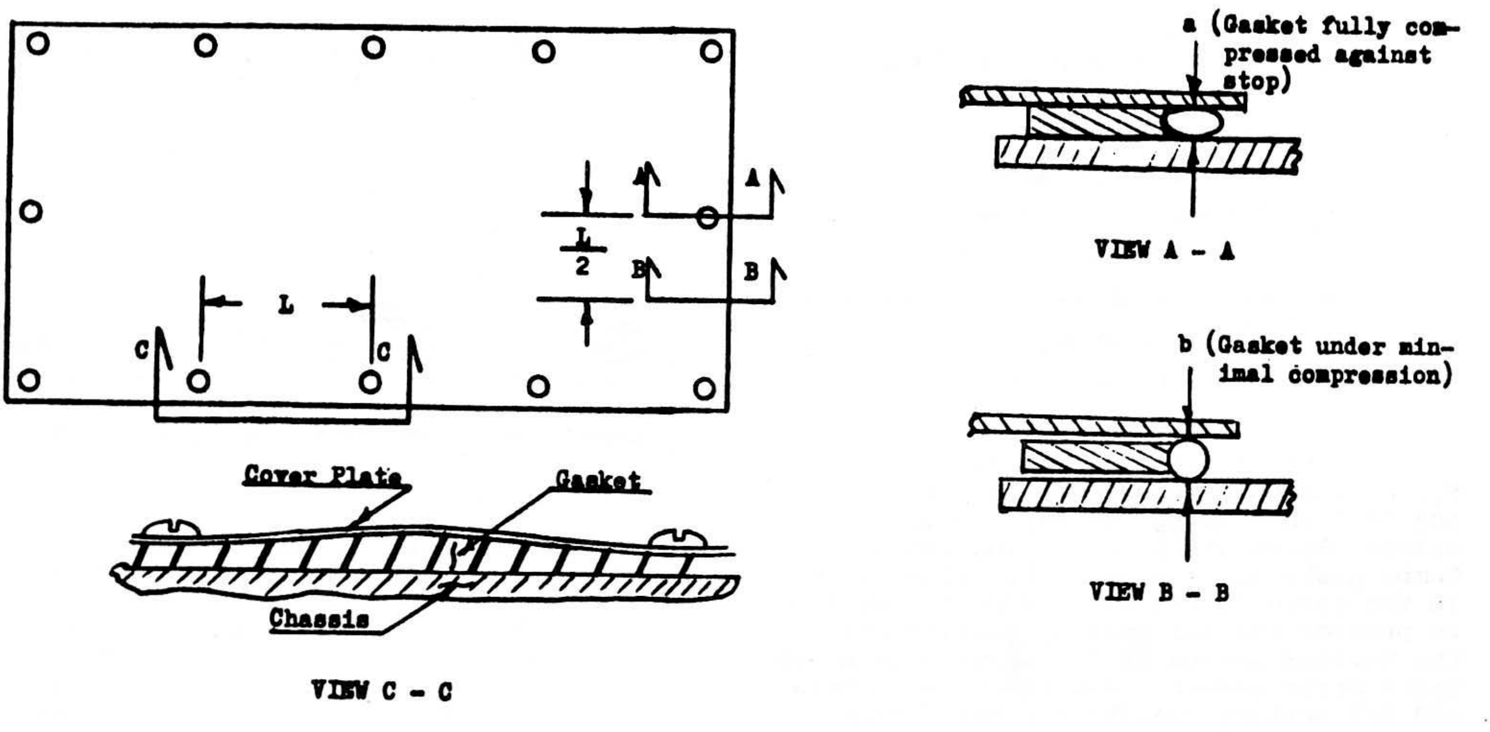


Figure 1. Typical Gasketed Cover Plate and Associated Views.

between the screws to obtain the minimum required impedance and the environmental seal. If the objective concerning the required force is met mid-way between the screws, then the requirements at all other places will be met.

DEFLECTION AND FORCE EQUATIONS

Equations 1 and 2 illustrate the basic fastener separation and fastener force equations. The length "L" between fasteners is in inches, and the force F_o is in pounds. The assumptions used in the development of the equations are that the cover (or beam) is parabolically loaded, fastened at both ends (as illustrated in figure 2) and that the bowing of the chassis can be neglected (see appendix B). The value "d" in equation 1 is the difference between "b" and "a" of figure 1 (see view B-B and A-A), and is the bowing of the cover. The value of F_1 is the critical minimum force that must be maintained on the gasket to obtain the desired shielding. The force F_2 in pounds per linear inch is the force required to be exerted on the gasket to deflect the gasket "d" (b-a) inches beyond the deflection obtained from F_1.

$$L = \left[\frac{480\ y\ E\ t^3\ d}{13\ F_1 + 2\ F_2}\right]^{1/4} \qquad \text{Fastener Separation (in)} \qquad (1)$$

$$F_o = \frac{(2F_1 + F_2)\ L}{3} \qquad \text{Fastener Force (lbs)} \qquad (2)$$

where:

- **y = Apparent width of cover flange** (in) **(Assume 1 inch if not distinct)**
- **t = Thickness of cover edge** (in)
- **d = Δ deflection of gasket (b–a)** (in)
- F_1 = **Minimum force on gasket** (lbs/in)
- F_2 = **Maximum force on gasket** (lbs/in)
- **E = Modulus of Elasticity of cover plate**
  - **=** 10^7 **for Aluminum** (psi)
  - **=** 3×10^7 **for Steel** (psi)

Table I illustrates the values of F_1, F_2 and d to be used in calculating "L" and "F_o" when using the various Spira Shield, Spira Strip and O Ring Spira Combo gaskets. The force F_1 illustrated in the table is the minimum force required to provide the EMI sealing quality for the various series of the Spira Shield and Spira Strip gaskets, and the environmental and EMI sealing quality for the O Ring Spira Gaskets.

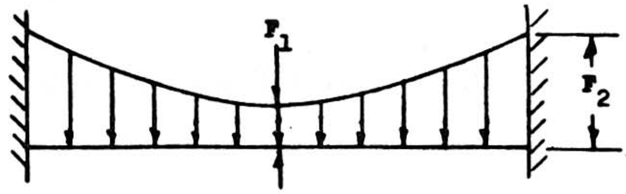


Figure 2. Loading of Cover Plate by Gasket.

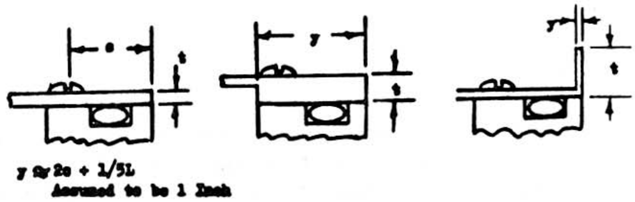


Figure 3. Various Cover Plate Arrangements.

Table I. Force and Deflection Variables for the Spira Shield, Spira Strip and O Ring Spira Combo Gaskets.

GASKET VARIABLES	GASKET SERIES						
	HI	SS	MS	LS	VLF	ORSS	ORMS
F_2 (lbs/In)	30	30	10	1.5	.1	30	10
F_1 (lbs/In)	6	.3	.3	.1	.04	8	4
d (Inches)	.20D	.25D	.25D	.20D	.15D	.18D	.15D

D = Diameter of EMI/RFI Sealing Spiral

Table II illustrates the values of F_1, F_2 and d to be used for calculating "L" and "F_o" when using the Basic Spira Combo gasket. The resultant seal will provide for a positive moisture and EMI joint.

Table II. Force and Deflection Variables for the Basic Spira Combo Gaskets.

GASKET VARIABLES	GASKETS					
	CHI-0625	CSS-0625	CMS-0625	CHI-0834	CSS-0834	CMS-0834
F_2 (lbs/In)	33	33	13	34	34	34
F_1 (lbs/In)	8	3	3	17	12	12
d (Inches)	.018	.025	.025	.025	.031	.031

Examples of the use of equations 1 and 2 and the contents of tables I and II are as follows:

1. What will the maximum fastener spacing and force using a 1/8 inch diameter Spira Shield gasket and a .090 inch thick aluminum cover of figure arrangement

3a.

$$L = \left[\frac{(480)(1)(10^7)(.090)^3(.031)}{13\ (.3) + 2\ (30)}\right]^{1/4}$$

$$= 6.4 \text{ inches}$$

$$F_o = \frac{[2(.3) + 30]\ 6.4}{3} = 65.5 \text{ lbs.}$$

2. What will the force versus fastener spacing be using a cover arrangement of 3c with t = 1/2 and y = .060 and a 1/8 inch diameter Spira Shield LS series gasket.

In solving this question, the value of "d" must be allowed to vary from .001 to .020 and F_2 must be in terms of "d". The value of F_2 is as follows:

$$F_2 = F_1 + \frac{(F_2' - F_1)\ d}{d'}$$

where: d' is the maximum recommended deflection from table 7 to deflect the gasket a distance of d'.

Letting d = .001

$$L = \left[\frac{480(.060)(10^7)(.5)^3(.001)}{13(.1) + 2(.17)}\right]^{1/4}$$

$$= 12.2 \text{ inches}$$

$$F_o = \frac{[2(.1) + .17]\ 12.2}{3} = 1.5 \text{ lbs.}$$

& "L" and "F_o" as a function of "d" is

	d(inches)			
	.001	.004	.1010	.020
L	12.2	16.3	20.3	22.5
F_o	1.5	3.2	6.8	12.8

A positive EMI and pressure seal can be obtained using the Spira Strip gaskets where the spiral provides the EMI seal and the 60 durometer neoprene elastomer provides the pressure seal. Equations 3 and 4 have been derived to provide the fastener spacing and force information when using the Spira Strip gasket for a pressure seal. The values of F in the equations are used for compressing the spiral and P times B illustrate the force required to compress the rubber elastomer. The value of $F_1 + P_1B$ is of sufficient force to compress the rubber .0005 inches. This compression in turn is sufficient to provide a pressure seal for one atmosphere (a differential of 14.7 pounds per square inch of pressure across the joint) when using smooth finished aluminum chassis and cover materials. In using the equation for deriving "L", the value of "d" must be selected and solve for L and F_o as a function of "d".

As an example of using equation 3 and 4, and an SS-0842 Spira Strip gasket

$$L = \left[\frac{480\ y\ E\ t^3\ d}{13(F_1+P_1B) + 2(F_2+P_2B)}\right]^{1/4} \quad \text{Fastener Separation (in)} \qquad (3)$$

$$F_o = \frac{[2(F_1+P_1B) + (F_2+P_2B)]\ L}{3} \quad \text{Fastener Force (lbs)} \qquad (4)$$

where:

y = Apparent width of cover flange (in)

E = Modulus of Elasticity of cover plate

= 10^7 for Aluminum (psi)

= 3×10^7 for Steel (psi)

t = Thickness of cover edge (in)

d = Δ deflection of rubber strip (in)

F_1 = Minimum force on EMI spiral

= 8 lbs/In for SS & 11 lbs/In for NI

F_2 = Maximum force on EMI spiral

= F_1 + 120d/D (lbs/in)

P_1 = Minimum Pressure on Rubber Strip

= 1.25/A (psi)

P_2 = Maximum Pressure on Rubber Strip

= (1.25 + 2500d)/A (psi)

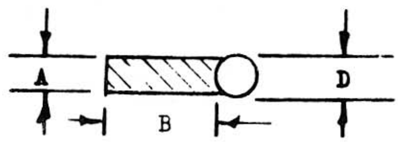
A = Thickness of Rubber Strip (in)

B = Width of Rubber Strip (in)

D = Diameter of EMI Spiral (in)

= A + 5% ± 3% for SS and

A + 8% ± 3% for NI



material to obtain a positive EMI and pressure seal with a flat aluminum cover of .125 inches thick and calculating for a "d" of .002, the maximum fastener spacing is 3.09 inches and will require a minimum fastener force of 57.5 pounds. i.e.,

A = .125, B = .250, D = .131,
d = .002, y = 1 & t = .125

$$L = \left[\frac{(480)(1)(10^7)(.125)^3(.002)}{13(8 + 2.5) + 2(9.83 + 25)}\right]^{1/4}$$

$$= 3.69 \text{ inches}$$

$$F_o = \frac{[2(8 + 2.5) + (9.83 + 25)]L}{3}$$

$$= 57.5 \text{ lbs.}$$

To optimize the value of "L" and "F_o" the equations should be performed several times allowing "d" to vary (see figure 7 for complete summation).

CONCLUSION

The selection of the fasteners and the subsequent spacing and force required to obtain a positive EMI and environmental seal is a significant problem to the design engineering community. Complicating the design problem even further is the fact that the selection of the gaskets available for use requires different levels of force to obtain the required sealing where such information is not readily available in published literature. The development of the equations illustrated herein were generated to eleviate this problem. Their utilization by the design engineering community can significantly reduce the manufacturing uncertanties and costs associated with the selection and use of EMI and environmental seals.

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APPENDIX A

DEVELOPMENT OF DEFLECTION AND FORCE EQUATIONS

The problem associated with the bowing of the cover due to the force of a gasket on the cover edge is identical to classical beam problems. Assuming as a close approximations, that the gasket load on the cover edge is parabolic as illustrated in figure 2. The loading as a function of F_1 and F_2 is:

$$= \frac{4(F_2 - F_1)\,x^2}{L^2} - \frac{4(F_2 - F_1)\,x}{L} + F_2 \qquad (5)$$

Solving for the deflection assuming a simple statically indeterminate beam with a constant EI, fixed at both ends yields

$$y(x) = -\frac{[(4F_2 + F_1)\,L^2]\,x^2}{120\,EI} + \frac{[(2F_2 + F_1)\,L]\,x^3}{36\,EI} + \frac{[F_2]\,x^4}{24EI} - \frac{[F_2 - F_1]\,x^5}{30\,EIL} + \frac{[F_2 - F_1]\,x^6}{90\,EIL^2} \qquad (6)$$

Since the deflection is the greatest at the mid-point or at $x = L/2$, y(max) is

$$y(max) = b-a = \frac{(2F_2 + 13F_1)\,L^4}{5760\,EI} \qquad (7)$$

Solving for the fastener spacing "L"

$$L = \left[\frac{(b-a)\,5760\,EI}{13F_1 + 2F_2}\right]^{1/4} \qquad (8)$$

Since $I = \frac{t^3}{12}$ and $b-a = d$, "L" becomes

$$L = \left[\frac{480\,y\,E\,t^3\,d}{13F_1 + 2F_2}\right]^{1/4} \qquad (9)$$

Equation 9 assumes that the chassis to which the cover plate is attached is rigid (or the bowing is small enough to be ignored). In the event that this assumption is not true then equation 8 becomes

$$L = \left[\frac{(b-a)\,5760\,EI\,E'\,I'}{(13F_1 + 2F_2)(EI + E'\,I')}\right]^{1/4} \qquad (10)$$

where:

- I - moment of inertia of cover plate edge strip (in^4)
- t - thickness of cover plate edge strip (inch)
- y - width of cover plate edge strip (knch)
- F_1 - minimum gasket force (lbs)
- F_2 - maximum gasket force (lbs)
- b - minimum gasket deflection (inch)
- a - maximum gasket deflection (inch)
- E - modulus of elasticity of cover plate (psi)
  - 10×10^6 psi for aluminum
  - 30×10^6 psi for steel
- L - fastener spacing (inch)
- F_o - tension load in bolts (lbs)
- I'- moment of inertia of chassis surface (in^4)
- E'- modulus of elasticity of chassis surface (psi)
- d - (b-a) deflection

RESULTS OF ANALYSIS VARYING THE GASKET MATERIALS AND COVER PLATE THICKNESS

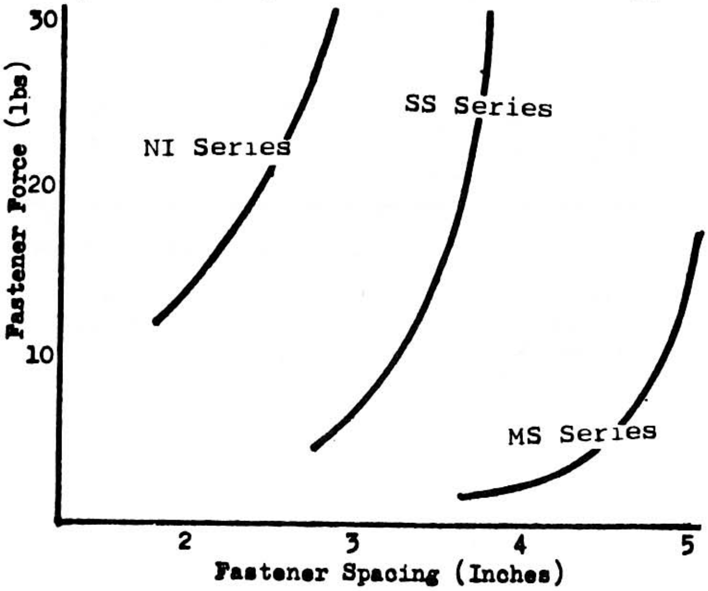
The contents of Appendix B illustrates the results of analysis performed on the various EMI-Environmental gaskets manufactured by Spira Manufacturing Corporation. In performing the analysis, the values of "L" and "F_o" were obtained as a function of "d", where d was allowed to vary from .001 to the values illustrated in tables I and II.

Figure 5 illustrates the results using the Spira Shield and Spira Strip gaskets where only EMI sealing is required. The four (4) illustrations relate to four different conditions varying the diameter of the spiral and the thickness of the cover plate.

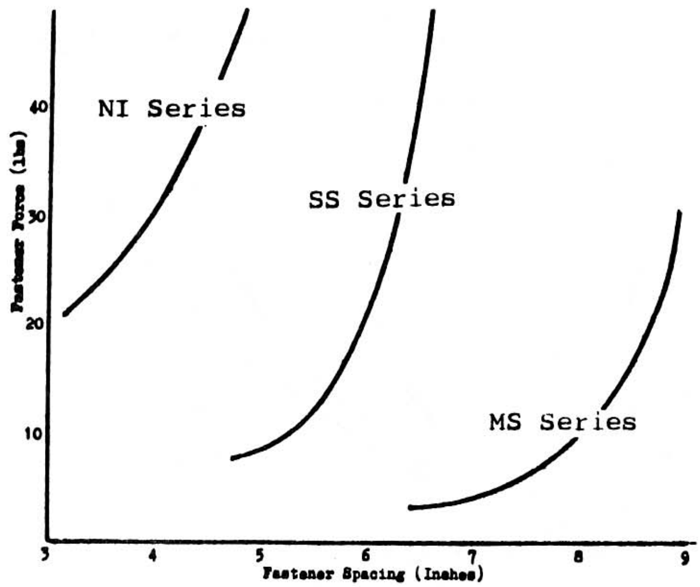
Figure 6 illustrates the results using a Basic Spira Combo Gasket and an O Ring Spira Combo gasket, where EMI and moisture sealing are required. The illustrations show 2 different thicknesses for the cover plate.

Figure 6 illustrates the results using the O Ring Spira Combo gasket as an EMI and pressure seal. The illustration shows the results for two different diameters of the gasket and two different thicknesses of cover plates.

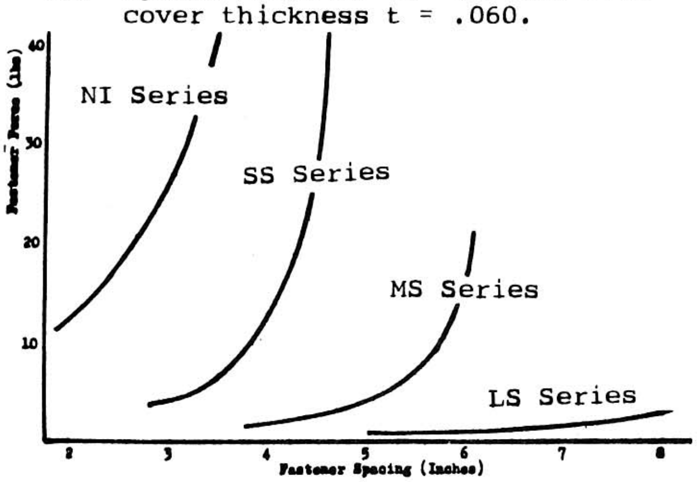
Figure 7 illustrates the results using the Spira Strip gasket as an EMI and a pressure seal. The illustration shows the results for two different gaskets using two different thicknesses of cover plates.



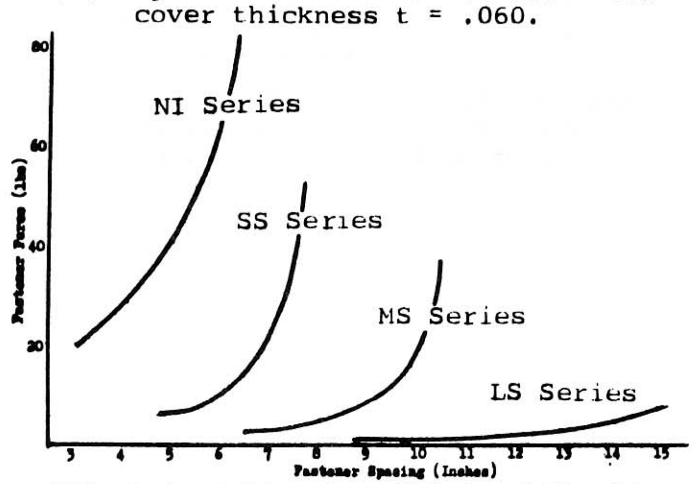
(a) Spiral Diameter "D" is .062 with cover thickness t = .060.



(b) Spiral Diameter "D" is .125 with cover thickness t = .060.



(c) Spiral Diameter "D" is .062 with cover thickness "t" = .125.



(d) Spiral Diameter "D" is .125 with cover thickness "t" = .125.

Figure 4. Fastener Spacing vs. Fastener Force using Spira Shield & Spira Strip Gasket Material - Covers are Flat.

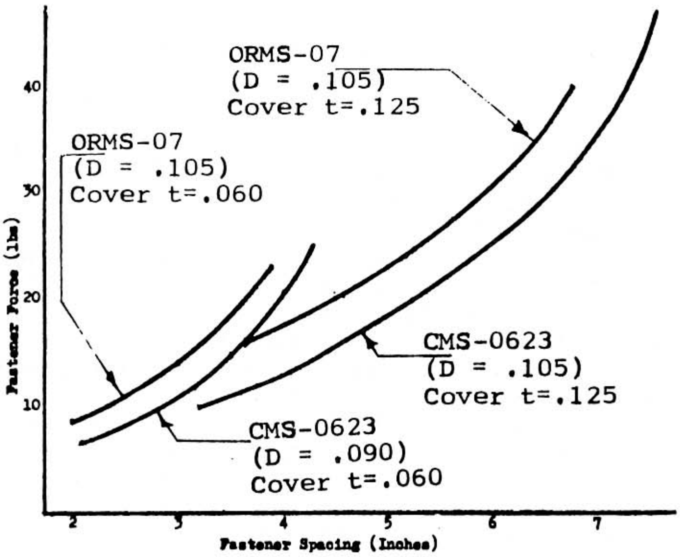


Figure 5. Fastener Force vs. Fastener Spacing for EMI and Moisture Sealing using O Ring Spira Combo and Basic Spira Combo Gasket Materials.

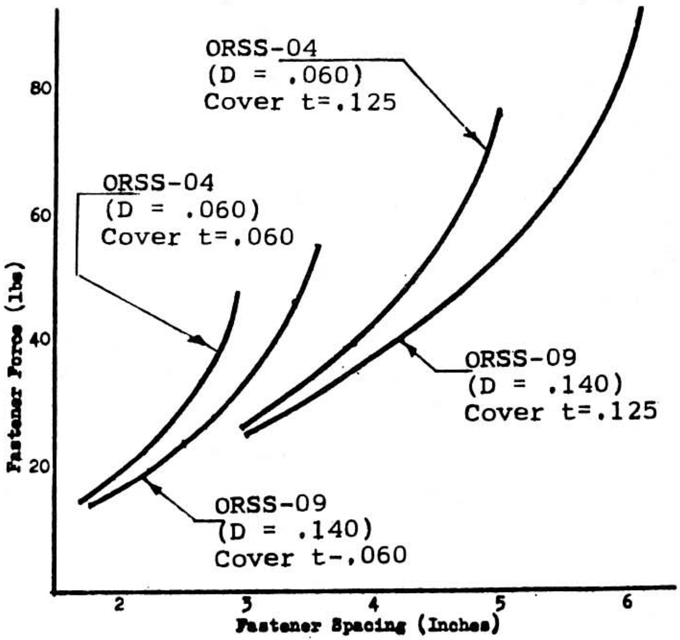


Figure 6. Fastener Force vs. Fastener Spacing for EMI and Pressure Sealing using O Ring Spira Combo Gasket Material.

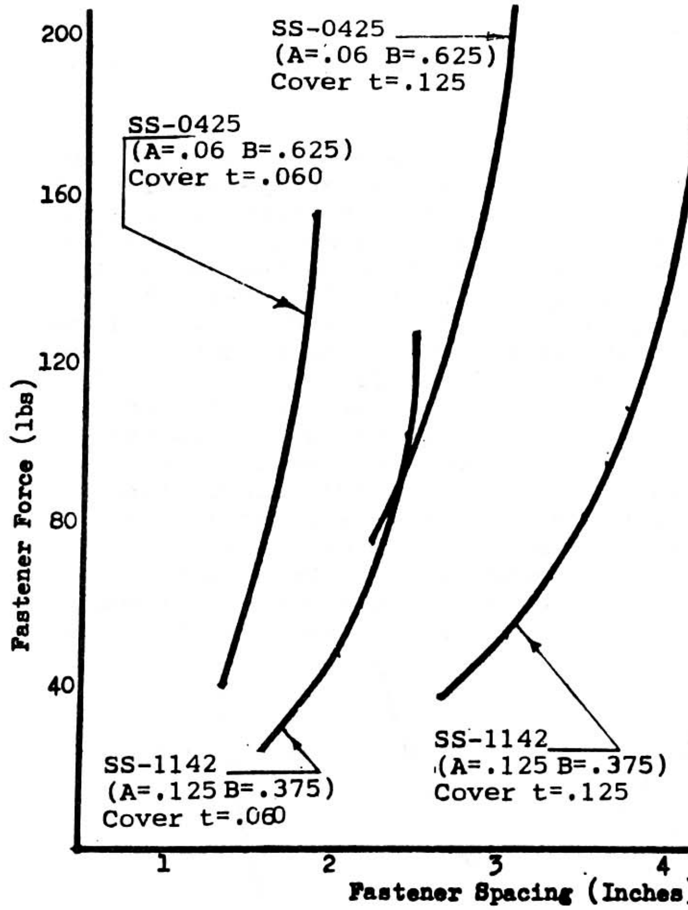


Figure 7. Fastener Force vs. Fastener Spacing for EMI and Pressure Sealing using Spira Strip Gasket Material.